Tomographic study of 3D distribution of the ionospheric electron density anomalies before and after the 2011 Tohoku-oki eq.

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Based on the ionospheric total electron content (TEC) observations using Global Navigation Satellite System (GNSS) satellites, we reported that TEC showed anomalies immediately before large earthquakes (Heki, 2011GRL; Heki & Enomoto, 2013JGR; 2015JGR). The leading times and the intensities of the anomalies in the 18 earthquakes of Mw7.3-9.2 (He & Heki, 2017JGR) showed clear scaling laws, i.e. they scale with the fault lengths and fault areas, respectively, suggesting that large earthquakes know their final sizes when the fault ruptures start. He & Heki (2018JGR) studied the three-dimensional (3D) distribution of the electron density anomalies before the 2015 Illapel earthquake (Mw8.3), Central Chile, and showed that the positive/negative electron density anomalies emerged in lower/upper ionosphere along the geomagnetic field. This let us hypothesize that the ionospheric electrons were redistributed in response to electric fields made by positive electric charges that appeared on the subaerial surface above the epicenter. These charges would have been mobilized by micro-scale cracks and dislocations as positive holes.

Here we apply the 3D tomography technique using the slant-TEC residual data in Japan and South Korea for the 2011 Tohoku-oki earthquake (Mw9.0). We found that the positive electron density anomaly appeared ~300 km above NE Japan (the anomaly does not extend to the sea, see attached figure). At the same time, a diffuse negative electron density anomaly appeared in the higher ionosphere. The electric current that flowed upward along the geomagnetic field makes an eastward geomagnetic field change of a few nT to the south of the epicenter, which is consistent with the change started ~40 minutes before the earthquake in Kakioka, NE Japan (Heki & Enomoto, 2013JGR). We also try to identify the 3D structure of the tsunamigenic ionospheric hole made by the 2011 Tohoku-oki earthquake.